VIII.—*Similar to* VII, *except that the preponderance of Antitoxin was greater, viz.*, 0·000075 *gram of venom and* 1 *c.c. of serum per kilogram of body weight in each case.*

Animal.	Weight in grams.	Time during which venom and serum were left in contact before heating.	Results.
i. Rabbit....	1025	Venom only (control)	Died in 12 hours.
ii. ,, ...	1190	2 minutes	,, 20 ,,
iii. ,, ...	1130	5 ,,	,, 28 ,,
iv. ,, ...	1060	10 ,,	Lived. Very ill 2 days.
v. ,, ...	1250	15 ,,	,, Ill 1 day.
vi. ,, ...	1210	30 ,,	,, No symptoms.
vii. ,, ...	1070	Not heated at all	,, ,,

IX.—*Similar to* VII *and* VIII, *but the preponderance of Serum is still greater, viz.*, 0·00005 *gram of venom and* 1 *c.c. of serum per kilogram of body weight in each case.*

Animal.	Weight in grams.	Time during which venom and serum were in contact before heating.	Result.
i. Rabbit....	1070	Venom only (control)	Died in 15 hours.
ii. ,, ...	1200	2 minutes	Lived. Very ill for 2 days.
iii. ,, ...	1170	5 ,,	,, Off feed 1 day.
iv. ,, ...	1130	10 ,,	,, No symptoms.
v. ,, ...	1030	15 ,,	,, ,,
vi. ,, ...	1420	30 ,,	,, ,,
vii. ,, ...	1050	Not heated at all	,, ,,

The expenses involved in the foregoing research were in part defrayed from a grant made by the Government Grant Committee of the Royal Society.

"On the Source of the Röntgen Rays in Focus Tubes." By Alan A. Campbell Swinton. Communicated by Lord Kelvin, F.R.S. Received June 7,—Read June 16, 1898.

The writer has already described ("Some new Studies in Cathode and Röntgen Radiations," a discourse given at the Royal Institution on February 4, 1898) how he has found it possible to study by means of pin-hole photography the active area on the anti-cathode of a focus tube from which the Röntgen rays proceed.

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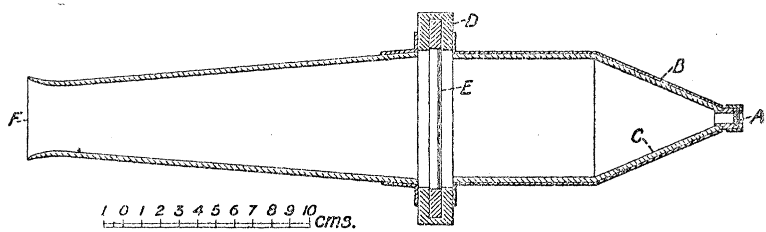
By means of a special camera he has now been able to make further investigations. The camera is illustrated in fig. 1, where A is the pinhole in a removable lead disc secured by a brass cap to the brass cone B, which is lined with thick lead so as to be opaque to the Röntgen rays. D is a framework into which slides either the fluorescent screen E, or a carrier containing a sensitive plate should photographs be required. F is an observation tube for use with the fluorescent screen. It is made of insulating material to avoid danger of shocks.

FIG. 1.

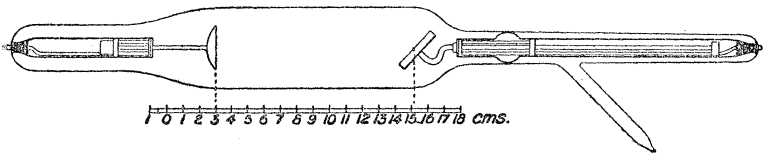


With this apparatus directed at the anti-cathode of a focus tube, it is easy with the fluorescent screen in place to take accurate note of the image of the active anti-cathode area which appears on the screen, and to observe the variations in form, dimensions, and brilliancy that take place under varying conditions. Similarly by replacing the fluorescent screen by a photographic plate in a black paper envelope, the Röntgen ray image can be photographed. Exposures, varying from one to thirty minutes, according to conditions, are found sufficient to impress upon the plate any effect that can be seen directly with the screen. It has not, however, been found possible, even with very prolonged exposures, to photograph anything not directly visible with the screen, and having regard to the difficulties of maintaining the vacuum and other conditions constant for any considerable length of time, the method of direct observation seems generally to be best and most convenient. For direct observation, rather a large pin-hole, say about 2 mm. in diameter, gives the best results; for photography about half this diameter is preferable, as it gives sharper images.

The writer has made numerous observations and photographs with this apparatus, both with focus tubes of the ordinary pattern, and also with a special tube in which both the cathode and also the anti-cathode (which in addition acted as anode) were independently adjustable along the axis of the tube, so that the distance between them could be varied from a minimum of 4 to a maximum of 14 cm. This special tube is illustrated in fig. 2, and during the

observations it was connected to a mercury pump, so that the degree of exhaustion could be varied as desired.

FIG. 2.



The following are the main effects observed.

(1) When the anti-cathode intersects the cathode stream at the focus, the dimensions of the active area are independent of the degree of exhaustion. For all other positions beyond the focus it is larger the lower the exhaustion and *vice versâ*. These observations are of course only possible between the limits of exhaustion with which Röntgen rays are produced.

(2) When the anti-cathode intersects the cathode stream beyond the focus, the active area is larger the greater the distance between cathode and anti-cathode. For instance, with the tube illustrated in fig. 2, exhausted to a good Röntgen ray vacuum, it was found that the active area gradually increased from about 0·15 cm. diameter with 4 cm. distance between cathode and anti-cathode up to about 2·3 cm. diameter as the distance was gradually increased to 14 cm. The increase is less the higher the vacua, but is always very considerable.

(3) When the anti-cathode intersects the cathode stream considerably beyond the focus, the active area is found to consist of a well defined and very intense central nucleus, surrounded by a much fainter but quite appreciable halo. Both of these increase in size as the distance between cathode and anti-cathode is increased.

In some cases the halo consists of a well marked hollow ring with a dark space between it and the central nucleus. In other cases two distinct concentric rings are visible surrounding the nucleus. Moreover, the nucleus itself, when very large, shows distinct signs of being made up of one or more concentric rings, sometimes with a still smaller nucleus within them. These observations correspond with and amplify what the writer has already noticed by direct observation of the visible luminescence of a carbon screen arranged to intersect the cathode stream.*

(4) With an anti-cathode inclined at an angle of 45° to the axis of the conical cathode stream, it is found that those portions of the stream which impinge most normally upon the anti-cathode

* 'Roy. Soc. Proc.,' vol. 61, pp. 81—84.

surface are considerably the most efficient in producing Röntgen rays. Similarly those portions of the stream that impinge on the anti-cathode surface very much on the slant are correspondingly ineffective in producing Röntgen rays.

(5) At the degrees of exhaustion most suitable for producing Röntgen rays, and with concave cathodes of the usual dimensions, the cathode stream proceeds almost entirely from a small central portion of the cathode surface, the remaining portion of the surface being apparently practically inoperative. That this is so was very conclusively established by photographs taken with the tube shown in fig. 2. In the manufacture or subsequent exhaustion of this tube three very minute fragments of glass by some means attached themselves on to the concave surface of the aluminium cathode, and remained fixed there during the experiments. The cathode itself was 29 mm. diameter, and the radial distances of the three glass fragments from the centre were respectively about 9 mm., 4 mm., and 2·5 mm. In all the pin-hole photographs of the anti-cathode of this tube in which the enlargement of the active area was sufficient, the shadows of the two glass fragments nearest to the centre of the cathode are clearly visible, while in none of them is there any appearance of the third and outer fragment. It, therefore, is evident that the whole of the cathode stream that was effective in producing Röntgen rays came from an area of the cathode surface less than 18 mm. diameter, or less than two-thirds of the full diameter of the cathode. Further, in each case the shadows of the two inner glass fragments appeared outside of the central nucleus, showing that the whole of the more intense portion of the cathode stream proceeded from a portion of the cathode surface less than 5 mm. in diameter. These results confirm the writer's observations made with carbon cathodes.*

(6) The different portions of the cathode stream proceeding from different portions of the cathode, cross at the focus and diverge in a cone that retains any special characteristics of the convergent cone. The relative positions of the two inner glass fragments on the cathode, and the positions and enlargement of their shadows on the anti-cathode for different distances between the latter and the cathode, were found to show this very clearly.

(7) Though by far the greater portion of the Röntgen rays given by a focus tube proceed from the active anti-cathode area, still, a very appreciable quantity is also given off by all those portions of the glass of the tube that show the green fluorescence.

Using a somewhat large pin-hole, this is easily observed by turning the tube so that the more powerful rays from the anti-cathode cannot reach the pin-hole, when a Röntgen ray image of the whole of the

* 'Roy. Soc. Proc.,' vol. 61, pp. 92—93.

fluorescent portions of the glass of the tube can be distinctly seen. Further, it is noticeable that that portion of the glass that shows the brightest fluorescence, *i.e.*, that part which lies in the path in which cathode rays would be reflected from the anti-cathode surface were they reflected according to the law of equal angles of incidence and reflection—gives off the most Röntgen rays, while those portions of the glass that show no fluoresence do not give off any Röntgen rays. The conclusion appears obvious that whatever produces the one also produces the other, but as has been pointed out by Professor S. P. Thompson* and others, the fluorescence is not due to the direct stream of rays from the cathode, which cannot reach portions of the glass that show fluorescence, but to some description of radiation that proceeds from the surface of the anti-cathode that faces the cathode. In the paper above referred to Professor Thompson calls these radiations "para-cathodic rays," stating that they differ from the Röntgen rays in respect of their power of penetration, and in their capacity of being electrostatically and magnetically deflectable. In these respects the writer's experiments confirm those of Professor Thompson, but when the latter goes on to differentiate these rays from ordinary cathode rays, on account of their not exciting Röntgen rays where they impinge on a solid surface, the writer is unable to agree, for, as above stated, these rays do excite Röntgen rays where they impinge upon the glass walls of the tube; as mentioned, however, they do this only to an extent that is relatively very feeble, and so far as the author knows only discernable by the pin-hole method of observation, which no doubt explains Professor Thompson's failure to observe the effect. The "para-cathodic" radiations in question do not, however, appear to be ordinary cathode rays. In the first place they do not proceed directly from the cathode, but only from the surface of the anti-cathode that faces the latter. Secondly, they do not appear to be negatively but positively charged, as can be ascertained by means of an exploring pole connected with an electroscope. The writer suggests that, assuming the correctness of the Crookes theory of the nature of the cathode rays, these "para-cathodic" rays may very probably consist of cathode ray particles which, having struck the anti-cathode, and having thus given up their negative charges and acquired positive charges, rebound, both by reason of their elasticity and also by repulsion from the anti-cathode. Perhaps owing to the comparative roughness of the anti-cathode surface, they fly off to some extent in all available directions, but they do so especially in that direction which the law of equal angles of incidence and reflection requires. It also appears very possible that these "paracathodic" rays are identical with the positively electrified streams proceeding from the anode, which the writer has

* See 'Phil. Trans.,' A., vol. 190, pp. 471—490.

investigated by means of radiometer mill wheels, recently described in a paper to the Physical Society.

In any case, it seems clear that in the tubes observed and photographed with the pin-hole camera, the Röntgen rays given off by certain portions of the fluorescent glass are not originated by the impact of an ordinary cathode stream, but apparently by the impact of positively charged streams proceeding from the anticathode.

The writer is greatly indebted to Mr. J. C. M. Stanton and Mr. H. Tyson Wolff, for the construction of the apparatus described, as also for valuable assistance in the carrying out of the experiments.

"On the Companions of Argon." By William Ramsay, F.R.S., and Morris W. Travers. Received June 13,—Read June 16, 1898.

For many months past we have been engaged in preparing a large quantity of argon from atmospheric air by absorbing the oxygen with red-hot copper, and the nitrogen with magnesium. The amount we have at our disposal is some 18 litres. It will be remembered that one of us, in conjunction with Dr. Norman Collie, attempted to separate argon into light and heavy portions by means of diffusion, and, although there was a slight difference* in density between the light and the heavy portions, yet we thought the difference too slight to warrant the conclusion that argon is a mixture. But our experience with helium taught us that it is a matter of the greatest difficulty to separate a very small portion of a heavy gas from a large admixture of a light gas; and it therefore appeared advisable to re-investigate argon, with the view of ascertaining whether it is indeed complex.

In the meantime, Dr. Hampson had placed at our disposal his resources for preparing large quantities of liquid air, and it was a simple matter to liquify the argon which we had obtained by causing the liquid air to boil under reduced pressure. By means of a two-way stopcock the argon was allowed to enter a small bulb, cooled by liquid air, after passing through purifying reagents. The two-way stopcock was connected with mercury gas-holders, as well as with a Töpler pump, by means of which any part of the apparatus could be thoroughly exhausted. The argon separated as a liquid, but at the same time a considerable quantity of solid was observed to separate partially round the sides of the tube, and partially below the

* Density of lighter portion, 19·93; of heavier portion, 20·01, 'Roy. Soc. Proc.,' vol. 60, p. 206.